

# **HYDRAULIC ENGINEERING LEGENDS LISTED ON THE EIFFEL TOWER**

Hubert Chanson<sup>1</sup>

<sup>1</sup>Professor in Civil Engineering, The University of Queensland, Brisbane QLD  
4072, Australia, Ph.: (61 7) 3365 4163, Fax: (61 7) 3365 4599, E-mail:  
h.chanson@uq.edu.au

**Abstract :** While the Eiffel Tower has become a landmark of Paris and France, few know about the names of 72 scientists engraved around the first floor. Herein, the names of 14 hydraulic engineers and scholars are reviewed and their selection is discussed. It is shown that most were leading engineers and lecturers during the French Revolution and early 19th century, and Gustave Eiffel's selection highlighted the influence of leading engineers on the French Society.

## **INTRODUCTION**

Built between 1887 and 1889, the Eiffel Tower (Tour Eiffel) was completed in 2 years, 2 months and 5 days for the International Exposition of 1889 in Paris (France) that marked the centenary of the French Revolution (Official Site of the Eiffel Tower 2008). Today the 120 years old structure is a landmark of the City of Paris and it faces the Trocadéro palace (Palais de Chaillot) built for the 1937 International Exposition, on the other side of the Seine River (Fig. 1). The Eiffel Tower stands on four lattice-girder piers that taper inward and join to form a single large vertical tower; as they curve inward, the piers are connected to each other by networks of girders at two levels that afford viewing platforms for tourists (Encyclopædia Britannica 2008). Interestingly, the four semicircular arches at the tower's base are aesthetic elements that serve no structural function (Fig. 1 and 2). The Tower's metallic structure weights 7,300 tons and consists of 18,038 iron parts and 2,500,000 rivets. The initial height was 312 m (current height: 324 m) and the Eiffel Tower was the world's highest building until 1929. Designed by Gustave Eiffel, the Tower was leased to Gustave Eiffel for 20 years before destruction. In 1909, the Tower was saved from demolition with the launch of wireless telegraphy. The Eiffel Tower hosted the first radiophonic (and later television) experiments in France and played further a crucial role during the World War I. Gustave Alexandre Eiffel (1832-1923) was a French civil and mechanical engineer who graduated from the Ecole Centrale des Arts et Manufactures in 1855. He specialised in metal construction, especially bridges. He designed several major structures including the Douro River bridge at Oporto (Portugal), the Garabit viaduct in southern France, the movable dome of the observatory at Nice (France) and the framework of the Statue of Liberty in New York Harbour (USA). Gustave Eiffel had a passion for aerodynamics and the Eiffel Tower shape was developed taking into account the wind resistance (Gallant 2002). Eiffel performed a series of observations on falling bodies using dedicated equipment installed in the Eiffel Tower from 1903 to 1905. He had also a small wind tunnel built at the foot of the tower in which he carried out five thousand tests from August to December 1909 (Hager 2003). He continued his aerodynamic research during World War I.



Fig. 1 - Eiffel Tower (Tour Eiffel), Paris, France on 8 July 2008 (Courtesy of Bernard Chanson) - View from Champ de Mars (Facade Ecole Militaire) with the Trocadéro in the background

The names of 72 scientists were engraved around the first floor of the Eiffel Tower as a tribute gesture from Gustave Eiffel (Fig. 2). In this sort contribution, the names of the hydraulic engineers and scientists listed on the Eiffel Tower are discussed. It is shown that most were leading engineers and lecturers during the French Revolution and first part of the 19th century.

### **HYDRAULIC ENGINEERS LISTED ON THE EIFFEL TOWER**

The names of the 72 scientists engraved around the first floor of the Eiffel Tower are listed in Table 1. In Table 1, the names numbered between 1 and 18 are on the Facade Trocadéro. The names numbered from 19 to 36 are engraved on the Facade Grenelle. The name numbers 37 to 54 are written on the Facade Ecole Militaire, while names numbered between 55 and 72 are listed on the Facade Paris. The names disappeared during one of the Eiffel Tower's repaintings at the turn of the 20th century and they were re-established in 1986-87. For example, the author lived in Paris between 1961 and 1986 and the names were not visible.

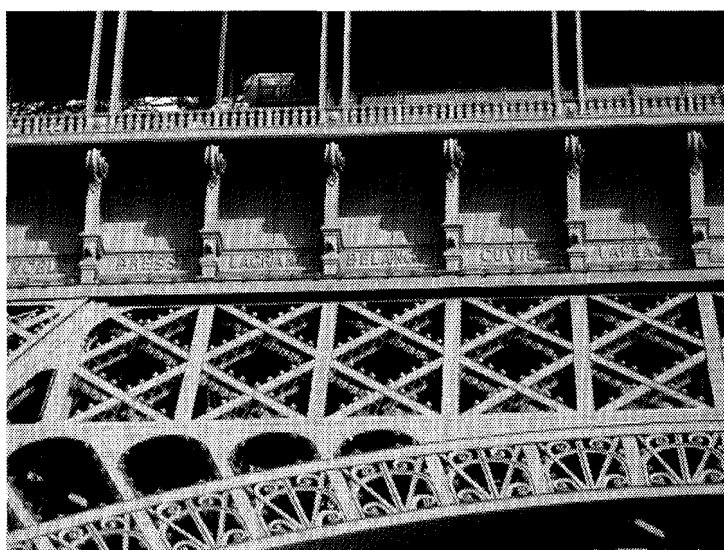
Several famous civil and mechanical engineers and scientists were listed, among which Jean-Baptiste Bélanger, Eugène Belgrand, Jean-Charles de Borda, Jacques Antoine Charles Bresse, Augustin Louis Cauchy, Gaspard-Gustave Coriolis, Jean Baptiste Joseph Fourier, Joseph-Louis Lagrange, Pierre-Simon Laplace, Gaspard Monge, Claude Louis Marie Henri Navier, Siméon Denis Poisson, Jean-Victor Poncelet, and Gaspard de Prony.

Jean-Baptiste-Charles-Joseph Bélanger (1789-1874) was a French hydraulician and professor at the Ecole des Ponts et Chaussées (Paris). He suggested first the application of the momentum principle to hydraulic jump flow (Bélanger 1841). Earlier, he presented the first backwater calculation for open channel flow

(Bélanger 1828, Chanson 2008,2009). As a lecturer at the Ecole Centrale, one of his students was Gustave Eiffel. Eugène Belgrand (1810-1878) was educated at Ecole Polytechnique. He made significant contributions to the modernisation of the Parisian sewer system, expanding its size fourfold between 1852 and 1869. Jean-Charles de Borda (1733-1799) was a French mathematician and military engineer. He achieved the rank of Capitaine de Vaisseau and participated in the U.S. War of Independence with the French Navy. He investigated the flow through orifices and developed the Borda mouthpiece. During the French Revolution, he worked with Joseph-Louis Lagrange and Pierre-Simon Laplace on the metric system. Jacques Antoine Charles Bresse (1822-1883) was a French applied mathematician and hydraulician. He was Professor at the Ecole des Ponts et Chaussées, Paris as the successor of J.B. Bélanger. His contribution to gradually-varied flows in open channel hydraulics is considerable (Bresse 1860). Augustin Louis de Cauchy (1789-1857) was a French engineer from the 'Corps des Ponts-et-Chaussées'. He devoted himself later to mathematics and he taught at Ecole Polytechnique, Paris, and at the Collège de France. He worked with Pierre-Simon Laplace and Joseph Louis Lagrange. In fluid mechanics, he contributed greatly to the analysis of wave motion. Gustave Gaspard Coriolis (1792-1843) was a French mathematician and engineer of the 'Corps des Ponts-et-Chaussées' who first described the Coriolis force: i.e., the effect of motion on a rotating body. He introduced the kinetic energy velocity correction coefficient named after him (Coriolis 1836). Jean Baptiste Joseph Fourier (1768-1830) was a French mathematician and physicist known for his development of the Fourier series, and his series of fundamental transport equations commonly used in environmental hydraulics. In 1794 he was offered a professorship of mathematics at the Ecole Normale in Paris and was later appointed at the Ecole Polytechnique. In 1798 he joined the expedition to Egypt lead by (then) General Napoléon Bonaparte. His research in mathematical physics culminated with the classical study "Théorie Analytique de la Chaleur" (Fourier 1822) presenting his heat conduction theory. Joseph-Louis Lagrange (1736-1813) was a French mathematician who introduced the concepts of stream function and velocity potential (Lagrange 1781, Chanson 2007). During the 1789 Revolution, he worked on the committee to reform the metric system. He was Professor of mathematics at the École Polytechnique from the start. Gaspard Monge (1746-1818), Comte de Péluse, was a French mathematician who invented descriptive geometry and pioneered the development of analytical geometry. He was a prominent figure during the French Revolution, helping to establish the Système métrique and the École Polytechnique, and being Minister for the Navy and colonies between 1792 and 1793. Claude Louis Marie Henri Navier (1785-1835) was a French engineer who primarily designed bridges but also extended Euler equations of motion, today called the Navier-Stokes equation (Navier 1823). Siméon Denis Poisson (1781-1840) was a French mathematician and scientist. He developed the theory of elasticity, a theory of electricity and a theory of magnetism; he also derived the Navier-Stokes equations in 1829 although by a different method than that used by Navier. Jean-Victor Poncelet (1788-1867) was a French engineer and mathematician, who studied at the Ecole Polytechnique and served in Napoleon's army. He developed and improved the design of turbines and water wheels. Gaspard Clair François Marie Riche de Prony (1755-1839) was a French mathematician and engineer. He succeeded Antoine Chézy as director general of the Ecole des Ponts et Chaussées, Paris during the French Revolution.



(A) Facade Ecole Militaire with the names of CAUCHY, BELGRAND, REGNAULT, FRESNEL, de PRONY and VIGAT

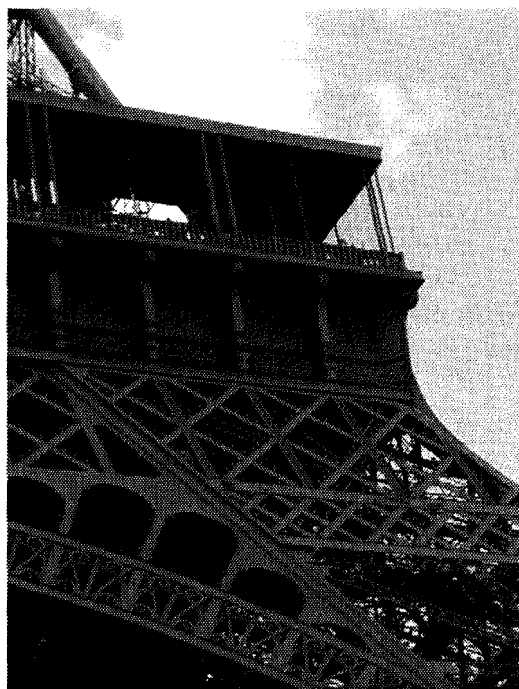


(B) Facade Trocadéro with the names of PONCELET (incomplete), BRESSE, LAGRANGE, BÉLANGER, CUVIER, and LAPLACE

Fig. 2 - Details of the engraved names of scientists on the Eiffel Tower on 25 July 2008

## SUMMARY AND DISCUSSION

In homage to the leading French scientists of the 19th century, Gustave Eiffel engraved 72 names around the Eiffel Tower, among which were Lazare Carnot (1753-1823), great-father of the French President in 1889 Marie François Sadi Carnot (1837-1894) together with 14 hydraulic engineers and scholars. The Tower was designed to last 20 years, and the selection of the scientists reflected Eiffel's opinion at the time. However Gustave Eiffel was criticised for some choices: e.g., the absence of scientists with long family names, and the absence of women such as Gabrielle Émilie Le Tonnelier de Breteuil, also known as Madame du Châtelet, (1706-1749) and Sophie Germain (1776-1831).



(C) Facade Ecole Militaire with the names of COMBES (incomplete), THENARD, ARAGO, POISSON and MONGE

Fig. 2 - (Continued)

In hydraulic engineering, it is the author's opinion that Gustave Eiffel acknowledged the leading scientists in the field of hydrodynamics and fluid mechanics. Yet one notes the absence of Henri Philibert Gaspard Darcy (1805-1858). This might be a consequence of Darcy's provincial career in Dijon, his short career lifespan and a lack of teaching involvement. It might also illustrate that some of Darcy's findings were not widely used until the 20th century (e.g. the Darcy friction factor). As an illustration, Bélanger (1849) was aware of Darcy's work in pipe flows, but he continued to use Prony's flow resistance formula for its simplicity (Chanson 2008). The omission of the names of Antoine Chézy (1717-1798) and Joseph Valentin Boussinesq (1842-1929) is noticeable but possibly understandable. Chézy was less famous and Boussinesq was still a young researcher in the 1880s.

Among the leading hydraulic engineers listed on the Eiffel Tower, half played an active role during the French Revolution and the Napoléon Era. Most were active lecturers (80%) in the leading French engineering schools. The latter illustrates the influence of engineering lecturers on the 19th century French engineering society. It shows also the pro-eminence of engineering studies on the French society: the 'Grandes Ecoles' system, still in use today, whose student recruitment is based upon competitive written and oral examinations. Notably these leading hydraulic scholars were educated mostly (57%) at the Ecole des Ponts et Chaussées and at the Ecole Polytechnique.

#### ACKNOWLEDGEMENTS

The writer acknowledges the advice and encouragements of Dr Jerry Rogers.

Table 1 - The names of the 72 scientists written around the Eiffel Tower, Paris (after Chanson 2008)

No	Name	No	Name	No	Name	No	Name
1	Marc SÉGUIN (1786-1875)	19	Jules Célestin JAMIN (1818-1889)	37	Auguste Louis CAUCHY (1789-1857)	55	Jules Alexandre PETIET (1813-1871)
2	Joseph Jérôme LEFRANCOIS de LALANDE (1732-1807)	20	Louis Joseph GAY-LUSSAC (1778-1850)	38	Eugène BELGRAND (1810-1878)	56	Louis Jacques MANDÉ DAGUERRE (1787-1851)
3	Henri TRESCA (1814-1885)	21	Hippolyte FIZEAU (1819-1896)	39	Henri V. REGNAULT (1810-1878)	57	Charles Adolphe WÜRTZ (1817-1884)
4	J.V. PONCELET (1788-1867)	22	Eugène SCHNEIDER (1805-1875)	40	Augustin Jean FRESNEL (1788-1827)	58	U.J.J. LE VERRIER (1811-1877)
5	Jacques Antoine Charles BRESSE (1822-1883)	23	Louis LE CHATELIER (1815-1873)	41	Gaspard de PRONY (1755-1839)	59	Jean Albert Vincent Auguste PERDONNET (1808-1867)
6	Joseph-Louis LAGRANGE (1736-1813)	24	Pierre BERTHIER (1782-1861)	42	Louis VICAT (1786-1861)	60	Jean-Baptiste Joseph DELAMBRE (1749-1822)
7	Jean-Baptiste-Charles-Joseph BÉLANGER (1790-1874)	25	Jean-Augustin BARRAL (1819-1884)	43	Jacques-Joseph EBELMEN (1814-1852)	61	Étienne Louis MALUS (1775-1812)
8	Baron Georges Leopold Chretien Frédéric Dagobert CUVIER (1769-1832)	26	Henri de DION (1828-1878)	44	Charles-Augustin de COULOMB (1736-1806)	62	Louis BREGUET (1804-1883)
9	Pierre-Simon LAPLACE (1749-1827)	27	Ernest GOUIN (1815-1885)	45	Louis POINSOT (1777-1859)	63	Camille POLONCEAU (1778-1847)
10	Pierre Louis DULONG (1785-1838)	28	Louis Didier JOUSSELIN (1776-1838)	46	Jean Bernard Léon FOUCAULT (1819-1868)	64	Jean Baptiste André DUMAS (1800-1884)
11	Michel CHASLES (1793-1880)	29	Paul Pierre BROCA (1824-1880)	47	Charles-Eugène DELAUNAY (1816-1872)	65	Benoît Paul Émile CLAPEYRON (1799-1864)
12	Antoine Laurent de LAVOISIER (1743-1794)	30	Antoine BECQUEREL (1788-1878)	48	Arthur MORIN (1795-1880)	66	Jean-Charles de BORDA (1733-1799)
13	André-Marie AMPÈRE (1775-1836)	31	Gaspard-Gustave CORIOLIS (1792-1843)	49	René Just HAÛY (1743-1822)	67	Jean Baptiste Joseph FOURIER (1768-1830)
14	Michel Eugène CHEVREUL (1786-1889)	32	Jean-François CAIL (1804-1871)	50	Charles COMBES (1801-1872)	68	Marie François Xavier BICHAT (1771-1802)
15	Eugène FLACHAT (1802-1873)	33	Jacques TRIGER (1801-1867)	51	Louis Jacques THÉNARD (1777-1857)	69	François Clément SAUVAGE (1814-1872)
16	Claude Louis Marie Henri NAVIER (1785-1835)	34	Henri GIFFARD (1825-1882)	52	Dominique François Jean ARAGO (1786-1853)	70	Théophile-Jules PELOUZE (1807-1867)
17	Adrien-Marie LEGENDRE (1752-1833)	35	François PERRIER (1833-1888)	53	Siméon Denis POISSON (1781-1840)	71	Lazare Nicolas Marguerite CARNOT (1753-1823)
18	Jean-Antoine CHAPTAL (1756-1832)	36	Jacques Charles François STURM (1803-1855)	54	Gaspard MONGE (1746-1818)	72	Gabriel LAMÉ (1795-1870)

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{ <a href="http://www.tour-eiffel.fr/">http://www.tour-eiffel.fr/</a> }	The Official Site of the Eiffel Tower
{ <a href="http://www-groups.dcs.st-and.ac.uk/~history/BiogIndex.html">http://www-groups.dcs.st-and.ac.uk/~history/BiogIndex.html</a> }	MacTutor History of Mathematics - Index of Biographies
{ <a href="http://espace.library.uq.edu.au/view/UQ:159418">http://espace.library.uq.edu.au/view/UQ:159418</a> }	Jean-Baptiste Charles Joseph Bélangier (1790-1874), the Backwater Equation and the Bélangier Equation
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